

REPORT DOCUMENTATION PAGE					Form Approved OMB No. 0704-01-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.						
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.						
1. REPORT DATE (DD-MM-YYYY) 16 Nov 2006		2. REPORT TYPE REPRINT			3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Reply to comment by M. Bodeau on "Charging of mirror surfaces in space"				5a. CONTRACT NUMBER		
				5b. GRANT NUMBER		
				5c. PROGRAM ELEMENT NUMBER 61102F		
6. AUTHORS Lai, Shu T.				5d. PROJECT NUMBER 5021		
				5e. TASK NUMBER RS		
				5f. WORK UNIT NUMBER A1		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory /VSBXT 29 Randolph Road Hanscom AFB, MA 01731-3010					8. PERFORMING ORGANIZATION REPORT NUMBER AFRL-VS-HA-TR-2006-1142	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/VSBXT	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for Public Release; distribution unlimited.						
13. SUPPLEMENTARY NOTES Reprinted from Journal of Geophysical Research, Vol. 111, doi:10.1029/2006JA011878, 2006.						
14. ABSTRACT Sputtering can slowly remove material from the surface of a spacecraft mirror, and even at low rates, will shorten the useful life of mirrors. Sputtering will only cause gradual degradation to solar cells, not the sudden stepwise degradation that sudden discharges can cause. These conclusions are not in disagreement with the comment of M. Bodeau. Future Boeing 702 series satellites will be equipped with conventional solar arrays, rather than mirrors. The main point in the Lai article is emphasized: the low photoemission of mirrors may cause differential charging if the space plasma is hot enough, as other parts of the satellite emit photoelectrons and the mirrors emit few photoelectrons.						
15. SUBJECT TERMS Spacecraft charging Space plasma physics Differential charging						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT		18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE				Shu T. Lai
UNCL	UNCL	UNCL	UNL		19b. TELEPHONE NUMBER (Include area code)	

Reply to comment by M. Bodeau on "Charging of mirror surfaces in space"

Shu T. Lai¹

Received 27 May 2006; revised 24 August 2006; accepted 30 August 2006; published 16 November 2006.

Citation: Lai, S. T. (2006), Reply to comment by M. Bodeau on "Charging of mirror surfaces in space," *J. Geophys. Res.*, **111**, A11219, doi:10.1029/2006JA011878.

[1] The first comment of *Bodeau* [2006] is about the Boeing ownership or acquisitions of companies and satellites. Since I had no knowledge of the companies or the details of acquisitions, and because this is not a scientific question, I will offer no further comment on this point. I thank M. Bodeau for this information.

[2] *Bodeau* [2006] comments at length, presenting supporting laboratory measurements, that sputtering rates are small and concludes that sputtering can not cause a sudden stepwise loss of power on Satellite PAS-7. Indeed, *Lai* [2005] has explored sputtering as a plausible mechanism and obtained a numerical estimate of the surface removal rate by sputtering. The rate obtained by *Lai* [2005] is of the order of 10^{-11} cm per month. The conclusion section in the work of *Lai* [2005] states: "Although the sputtering rate is small, prolonged sputtering would shorten the useful life of the mirrors. Unlike sudden discharges, which may cause damage or stepwise degradation to the solar cells, sputtering causes gradual degradation only to the solar cells." This conclusion of *Lai* [2005] is not in disagreement with that of *Bodeau* [2006].

[3] *Bodeau* [2006] comments that PAS-7 has no mirror. I thank M. Bodeau for this information. However, the PAS-7 articles posted on 27 and 28 September 2001 on SpaceToday.net (<http://www.spacetoday.net/Summary/408>) and SpaceDaily (<http://www.spacedaily.com/news/panamsat-01b.html>), respectively, show a satellite picture with mirrors flanking the solar panels. If PAS-7 does not feature mirrors, I agree that the proposed differential charging mechanism would not apply. For Boeing 702 satellites, see http://www.boeing.com/defense-space/space/bss/factsheets/702/galaxy_xi/galaxy_xi.html. As a

consequence of degradation, future 702 satellites will be equipped with conventional solar arrays (see the Sat-Index Web site, available at <http://www.sat-index.com/failures/702arrays.html>).

[4] The main point in the work of *Lai* [2005] is a novel postulate that mirrors of high reflectance emit little or no photoemission. With low photoemission, the mirrors may charge to high negative voltages even in sunlight, when the ambient space plasma is hot enough. Charging of mirrors has never been studied in the laboratory. If the satellite surfaces, including parts of the solar panels, emit abundant photoelectrons in sunlight, they would not charge, or charge to low positive potentials only. If so, differential charging may occur on the satellite more often than previously thought. It may occur not only during eclipse periods, which are indeed short, but also sometimes in sunlight when a critical temperature is exceeded. If PAS-7, or any satellite, does not feature reflectors, the proposed differential charging mechanism would not apply.

[5] **Acknowledgment.** Amitava Bhattacharjee thanks Henry Garrett for the assistance in evaluating this paper.

References

- Bodeau, M. (2006), Comments on "Charging of mirrors in space" by S. T. Lai, *J. Geophys. Res.*, **111**, A11218, doi:10.1029/2006JA011720.
- Lai, S. T. (2005), Charging of mirrors in space, *J. Geophys. Res.*, **110**, A01204, doi:10.1029/2002JA009447.

S. T. Lai, Space Vehicles Directorate, Air Force Research Laboratory, 29 Randolph Road, Hanscom Air Force Base, MA 01731-3010, USA. (shu.lai@hanscom.af.mil)

20070117041

¹Space Vehicles Directorate, Air Force Research Laboratory, Hanscom Air Force Base, Massachusetts, USA.